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Page 9 of 9

#### REMARKS

Claims 6-12 are pending in this application. By this Preliminary Amendment, Applicant AMENDS the specification and the abstract of the disclosure, CANCELS claims 1-5 and ADDS new claims 6-12.

Applicant has attached hereto a Substitute Specification in order to make corrections of minor informalities contained in the originally filed specification. Applicant's undersigned representative hereby declares and states that the Substitute Specification filed concurrently herewith does not add any new matter whatsoever to the above-identified patent application. Accordingly, entry and consideration of the Substitute Specification are respectfully requested.

The changes to the specification have been made to correct minor informalities to facilitate examination of the present application.

Applicant respectfully submits that this application is in condition for allowance. Favorable consideration and prompt allowance are respectfully solicited.

Respectfully submitted,



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**MARKED-UP VERSION OF  
ENGLISH TRANSLATION OF  
INTERNATIONAL APPLICATION  
AS ORIGINALLY FILED**

## DESCRIPTION

Attorney Docket No. 36856.1393

## ELECTRONIC COMPONENT DEVICE

Technical BACKGROUND OF THE INVENTION1. Field of the Invention

[0001] — The present invention relates to an electronic component device in which a rectangular plate-shaped electronic component element having a functional part thereon is mounted on a substrate with bumps. In further detail, the present invention relates to an electronic component device in which a rectangular plate-shaped electronic component element is mounted on a substrate so that a functional part of the electronic component element that is hermetically sealed. The electronic component element has a coefficient of linear expansion in the x direction along a side of the rectangle and a coefficient of linear expansion in the y direction orthogonal to the x direction in the plane of the rectangle, wherein the coefficients of linear expansion being different from each other, is hermetically sealed.

Background Art

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2. Description of the Related Art

[0002] Hitherto, various electronic component devices in which an electronic component element (hereinafter also abbreviated to as an element), such as a SAW element or a high-frequency element, is installed on a substrate have been

proposed.

[0003] —— For example, Japanese Unexamined Patent Document Application Publication No. 4-293310 discloses a surface acoustic wave device in which a SAW element is mounted on a base plate with bumps. In more detail, hot-side lands are provided on a surface of the base plate and solder bumps are provided on the corresponding hot-side lands. In addition, a frame-shaped earth-side land is provided on the surface of the base plate so as to surround the hot-side lands. A solder sealing frame is provided on the frame-shaped earth-side land. On the other hand, interdigital transducers (IDT), hot-side patterns, and earth-side patterns are provided on a surface of a SAW element chip to form a functional part. The SAW element is fixed on the base plate with a predetermined space therebetween such that the surface having the IDTs of the SAW element faces the surface of the base plate. The space is hermetically sealed with the solder sealing frame.

Patent Document 1: However, in the surface acoustic wave device described in Japanese Unexamined Patent Application Publication No. 4-293310

Disclosure of Invention

[0004] —— However, in the surface acoustic wave device described in Patent Document 1, the coefficient of linear expansion in the x direction along a side of the rectangular plate-shaped SAW element is different from the coefficient of linear expansion in the x direction of the base plate. In addition, the coefficient of linear expansion in the y direction, which lies in the plane of the rectangle of the SAW

element and is orthogonal to the x direction, is different from the coefficient of linear expansion in the y direction of the base plate. Thus, in the SAW element and the base plate, the coefficients of linear expansion in the same direction are different from each other. Therefore, when a thermal shock is applied during a reliability test or during use, a large difference in expansion is generated between the SAW element and the base plate. Consequently, a strain or a fatigue breaking is generated in the sealed portion, resulting in a sealing failure. This causes a problem that the lifetime for thermal shock resistance required for general electronic component devices cannot be satisfied.

~~An object of the present invention is~~

#### SUMMARY OF THE INVENTION

[0005] In order to overcome the problems described above, preferred embodiments of the present invention provide an electronic component device satisfying the lifetime for thermal shock resistance required for general electronic component devices and having excellent reliability.

[0006] The present invention provides~~The preferred embodiments provide~~ an electronic component device including a rectangular plate-shaped element including a front face, a reverse face, a functional part provided on the front face, and a first frame-shaped electrode surrounding the functional part, wherein the coefficient of linear expansion in the x direction along a side of the rectangle is different from the coefficient of linear expansion in the y direction orthogonal to the x direction in the rectangular plane; a substrate

including a front face, a reverse face, and a second frame-shaped electrode provided on the front face at a position corresponding to the first frame-shaped electrode; and a solder sealing frame provided on the surface of at least one of the first frame-shaped electrode and the second frame-shaped electrode. In the electronic component device, each of the first frame-shaped electrode, the second frame-shaped electrode, and the solder sealing frame includes a strip-shaped partportion extending in the x direction and a strip-shaped partportion extending in the y direction, the element and the substrate are bonded with the solder sealing frame, and the functional part provided on the front face of the element is hermetically sealed in a space formed between the element and the substrate. In the electronic component device, ~~when~~ the difference in expansion in the x direction between the element and the substrate is represented by  $Q_x$  and the difference in expansion in the y direction between the element and the substrate is represented by  $Q_y$ . Then, in each of the first frame-shaped electrode, the second frame-shaped electrode, and the solder sealing frame, the width of the strip-shaped partportion extending in the direction in which the larger difference in expansion is generated between the differences  $Q_x$  and  $Q_y$  in expansion is smaller than the width of the strip-shaped partportion extending in the direction in which the smaller difference in expansion is generated between the differences  $Q_x$  and  $Q_y$  in expansion.

[0007] ——According to ~~a specific aspect~~another preferred embodiment of the present invention, the thickness of the

solder sealing frame is about 18  $\mu\text{m}$  or more.

[0008] ——According to another ~~specifie aspect~~preferred embodiment of the present invention, when the coefficient of linear expansion in the x direction of the substrate is represented by  $A_x$ , and the coefficient of linear expansion in the y direction of the substrate is represented by  $A_y$ , the coefficient of linear expansion in the x direction of the element is represented by  $B_x$ , and the coefficient of linear expansion in the y direction of the element is represented by  $B_y$ , the length of the external side of the strip-shaped ~~part~~portion extending in the x direction of the first and second frame-shaped electrodes is represented by  $dl_x$ , and the length of the external side of the strip-shaped ~~part~~portion extending in the y direction of the first and second frame-shaped electrodes is represented by  $dl_y$ . Then, the difference  $Q_x$  in expansion is represented by  $Q_x = |A_x - B_x| \times dl_x$  (mm/ $^{\circ}\text{C}$ ), and the difference  $Q_y$  in expansion is represented by  $Q_y = |A_y - B_y| \times dl_y$  (mm/ $^{\circ}\text{C}$ ), the larger difference in expansion between the differences  $Q_x$  and  $Q_y$  in expansion is about  $2.2 \times 10^{-5}$  (mm/ $^{\circ}\text{C}$ ) or less.

[0009] ——According to another ~~specifie aspect~~preferred embodiment of the present invention, when the ratio of flexural rigidity in the x direction between the element and the substrate is represented by  $R_x$  and the ratio of flexural rigidity in the y direction between the element and the substrate is represented by  $R_y$ , the larger ratio of flexural rigidity between the ratios  $R_x$  and  $R_y$  of flexural rigidity is about 1.2 or less.

[0010] ——According to another specific aspectpreferred embodiment of the present invention, the element is a surface acoustic wave element.

[0011] ——In the electronic component device according to another preferred embodiment of the present invention, when the difference in expansion in the x direction between the element and the substrate is represented by  $Q_x$  and the difference in expansion in the y direction between the element and the substrate is represented by  $Q_y$ . Then, in each of the first frame-shaped electrode, the second frame-shaped electrode, and the solder sealing frame, the width of the strip-shaped partportion extending in the direction in which the larger difference in expansion is generated between the differences  $Q_x$  and  $Q_y$  in expansion is smaller than the width of the strip-shaped partportion extending in the direction in which the smaller difference in expansion is generated between the differences  $Q_x$  and  $Q_y$  in expansion. Therefore, the lifetime for thermal shock resistance can be improved, and thus the lifetime for thermal shock resistance required for general electronic component devices can be satisfied.

[0012] ——In the electronic component device according to another preferred embodiment of the present invention, when the thickness of the solder sealing frame is about 18  $\mu\text{m}$  or more, the lifetime for thermal shock resistance of the electronic component device can be further improved.

[0013] ——In the electronic component device according to another preferred embodiment of the present invention, when the larger difference in expansion between the differences  $Q_x$

and  $Q_y$  in expansion is about  $2.2 \times 10^{-5}$  (mm/ $^{\circ}$ C) or less, the lifetime for thermal shock resistance of the electronic component device can be further improved.

[0014] ——In the electronic component device according to another preferred embodiment of the present invention, when the larger ratio of flexural rigidity between the ratios  $R_x$  and  $R_y$  of flexural rigidity is about 1.2 or less, the lifetime for thermal shock resistance of the electronic component device can be further improved.

[0015] Other features, elements, steps, advantages and characteristics of the present invention will become more apparent from the following detailed description of preferred embodiments thereof with reference to the attached drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0016] ——[Fig. 1] Fig. 1 is a perspective view of an electronic component device according to an preferred embodiment of the present invention.

[0017] ——[Fig. 2] Fig. 2 is Figs. 2A and 2B are an exploded perspective view of the electronic component device shown in Fig. 1.

[0018] ——[Fig. 3] Fig. 3(a)A is a plan view of a package substrate used in the electronic component device in Fig. 1 and Fig. 3(b)B is a cross-sectional view taken along face A-A in Fig. 3(a)A.

[0019] ——[Fig. 4] Fig. 4(a)A is a plan view of an element used in the electronic component device in Fig. 1 and Fig. 4(b)B is a cross-sectional view taken along face B-B in

Fig. 4(a)A.

[0020] —— [Fig. 5] —— Fig. 5(a)A is a plan view of a solder sealing frame used in the electronic component device in Fig. 1 and Fig. 5(b)B is a cross-sectional view taken along face C-C in Fig. 5(a)A.

[0021] —— [Fig. 6] —— Fig. 6 is a graph showing the relationship between the thickness of a solder sealing frame and the maximum amplitude of equivalent strain.

[0022] —— [Fig. 7] —— Fig. 7 is a graph showing the relationship between the difference in expansion and the maximum amplitude of equivalent strain.

[0023] —— [Fig. 8] —— Fig. 8 is a graph showing the relationship between the ratio of flexural rigidity and the maximum amplitude of equivalent strain.

Reference Numerals

- 1 — package substrate
- 2 — bonding electrode
- 3 — second frame shaped electrode
- 4 — solder sealing frame
- 10 — element
- 11 — piezoelectric substrate
- 12 — IDT
- 13 — input output electrode
- 14 — first frame shaped electrode
- 15 — bump
- 20 — electronic component device

Best Mode for Carrying Out the Invention

— DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0024] As described above, when a thermal shock is applied to the known electronic component device during a reliability test or during use, a strain or a fatigue breaking is generated in the sealed portion, resulting in a problem of sealing failure. For example, in order to check if the lifetime for thermal shock resistance ((high temperature side 85°C, low temperature side -55°C, 30 minutes each/1 cycle) × 500 cycles) required for general electronic component devices is satisfied, a thermal shock resistance test was performed (under the same condition as that in the lifetime for thermal shock resistance) using the known electronic component device. As a result, the sealed portion was broken because of a large difference in expansion, resulting in the sealing failure. Thus, the lifetime for thermal shock resistance could not be satisfied.

[0025] —To evaluate the lifetime for thermal shock resistance, for example, a shock is forcibly applied so that a strain is generated at a joined portion by a solder ball. In this case, the empirical equation of "the Coffin-Manson's law" derived for the resultant strain and the lifetime for thermal shock resistance is represented as follows: (maximum amplitude of equivalent strain) =  $0.325 \times (\text{lifetime (cycle)})^{-0.429}$  (refer to "Kairo jisso gakkaishi" (The Journal of Japan Institute for Interconnecting and Packaging Electronic Circuits), Vol. 12, No. 6 (1997), pp. 413-417, Fig. 7).

[0026] —The maximum amplitude of equivalent strain in this empirical equation means the dimension of amplitude caused by expansion and contraction of solder during the

thermal shock resistance test of an electronic component device. Accordingly, it is known that reducing the maximum amplitude of equivalent strain can improve the lifetime for thermal shock resistance of the electronic component device.

[0027] ——The above empirical equation is an equation relating to the fatigue life (lifetime for thermal shock resistance) for solder bumps. However, since the strain generated in solder is a parameter with generality, this equation can be applied to the lifetime for thermal shock resistance of a sealing frame or the like.

[0028] ——The maximum amplitude of equivalent strain when a thermal shock was applied corresponding to the condition for the lifetime for thermal shock resistance required for general electronic component devices was applied was calculated as about 2.2% by an FEM simulation. In other words, when the maximum amplitude of equivalent strain can be decreased to about 2.2% or less, the lifetime for thermal shock resistance required for general electronic component devices can be satisfied.

[0029] ——Fig. 6 is a graph showing the relationship between the thickness of solder and the maximum amplitude of equivalent strain. As shown in Fig. 6, in order to control the maximum amplitude of equivalent strain to about 2.2% or less, the thickness of the solder should be about 18  $\mu\text{m}$  or more.

[0030] ——Fig. 7 is a graph showing the relationship between the difference in expansion and the maximum amplitude of equivalent strain. As shown in Fig. 7, in order to control

the maximum amplitude of equivalent strain to about 2.2% or less, the difference in expansion should be about  $2.2 \times 10^{-5}$  mm/ $^{\circ}$ C or less.

[0031] ——Fig. 8 is a graph showing the relationship between the ratio of flexural rigidity and the maximum amplitude of equivalent strain. As shown in Fig. 8, in order to control the maximum amplitude of equivalent strain to about 2.2% or less, the ratio of flexural rigidity should be about 1.2 or less.

[0032] ——That is, the present inventor has found that, in order to control the maximum amplitude of equivalent strain to about 2.2% or less, the thickness of the solder sealing frame should be about 18  $\mu$ m or more, the larger difference in expansion between the differences  $Q_x$  and  $Q_y$  in expansion should be about  $2.2 \times 10^{-5}$  mm/ $^{\circ}$ C or less, and the larger ratio of flexural rigidity between the ratios  $R_x$  and  $R_y$  of flexural rigidity should be about 1.2 or less.

[0033] ——Furthermore, the present inventor has found the following: In each of the solder sealing frame, a first frame-shaped electrode, and a second frame-shaped electrode, when the width of a strip-shaped part—portion extending in the direction in which the larger difference in expansion is generated between the differences  $Q_x$  and  $Q_y$  in expansion is smaller than the width of a strip-shaped part—portion extending in the direction in which the smaller difference in expansion is generated between the differences  $Q_x$  and  $Q_y$  in expansion, the lifetime for thermal shock resistance of the electronic component device can be improved.

[0034] ——Herein, each of the differences  $Q_x$  and  $Q_y$  in expansion means the differences between the coefficient of expansion of a substrate and the coefficient of expansion of an element. The difference  $Q_x$  in expansion in the x direction between the element and the substrate and the difference  $Q_y$  in expansion in the y direction between the element and the substrate are represented by equations of  $Q_x = |A_x - B_x| \times d_{l_x}$  (mm/ $^{\circ}$ C) and  $Q_y = |A_y - B_y| \times d_{l_y}$  (mm/ $^{\circ}$ C), respectively, wherein  $A_x$  represents the coefficient of linear expansion in the x direction of the substrate,  $A_y$  represents the coefficient of linear expansion in the y direction of the substrate,  $B_x$  represents the coefficient of linear expansion in the x direction of the element,  $B_y$  represents the coefficient of linear expansion in the y direction of the element,  $d_{l_x}$  represents the length of the external side of the strip-shaped partportion extending in the x direction of the first frame-shaped electrode and the second frame-shaped electrode, and  $d_{l_y}$  represents the length of the external side of the strip-shaped partportion extending in the y direction thereof.

[0035] ——Herein, each of the ratios  $R_x$  and  $R_y$  of flexural rigidity means the ratio of flexural rigidity of a substrate and the flexural rigidity of an element. The ratio  $R_x$  of flexural rigidity in the x direction between the substrate and the element and the ratio  $R_y$  of flexural rigidity in the y direction between the substrate and the element are represented by equations of  $R_x = (at^3 \cdot a_x \cdot Ea) / (bt^3 \cdot b_x \cdot Eb)$  and  $R_y = (at^3 \cdot a_y \cdot Ea) / (bt^3 \cdot b_y \cdot Eb)$ , respectively, wherein  $at$  represents the thickness of the substrate,  $a_x$  represents the length of a

side extending in the x direction of the substrate,  $a_y$  represents the length of a side extending in the y direction of the substrate,  $Ea$  represents the Young's modulus of the substrate,  $bt$  represents the thickness of the element,  $b_x$  represents the length of a side extending in the x direction of the element,  $b_y$  represents the length of a side extending in the y direction of the element, and  $Eb$  represents the Young's modulus of the element.

[0036] — Specific, non-limiting preferred embodiments of the present invention will now be described with reference to the drawings, thereby clarifying the present invention.

[0037] — Fig. 1 is a perspective view of an electronic component device 20 according to an preferred embodiment of the present invention and Fig. 2 is s. 2A and 2B are an exploded perspective view of the electronic component device 20. In the electronic component device 20, an element 10 is mounted face-down on a package substrate 1.

[0038] — Fig. 3(a)A is a plan view of a package substrate used in the electronic component device 20 and Fig. 3(b)B is a cross-sectional view taken along a face including line A-A in Fig. 3(a).A. The package substrate 1 is an airtight flat plate component ~~and is composed~~made of a glass epoxy resin having airtightness. The length  $a_x$  of a side extending in the x direction of the package substrate 1 is 2.0 mm, the length  $a_y$  of a side extending in the y direction is 2.0 mm, the thickness at is 0.25 mm, and the Young's modulus  $Ea$  is 340,000 MPa. Both the coefficient  $A_x$  of linear expansion in the x direction of the package substrate 1 and the coefficient  $A_y$  of

linear expansion in the y direction thereof are 7 ppm/ $^{\circ}$ C.

[0039] ——As shown in Fig. 3(a)A, four rectangular plate-shaped bonding electrodes 2 and a frame-shaped electrode 3 serving as a second frame-shaped electrode (the frame-shaped electrode 14, described below, serves as the first frame-shaped electrode) are provided on the surface of the package substrate 1. The second frame-shaped electrode 3 is disposed so as to surround the bonding electrodes 2. The bonding electrodes 2 are connected to outer electrodes (not shown in the figure) for surface mounting, the outer electrodes being provided on the reverse face, via connecting portions in which an electrode material is embedded in through-holes (not shown in the figure). The frame-shaped electrode 3 is connected to an earth-side electrode (not shown in the figure).

[0040] ——The frame-shaped electrode 3 has a rectangular frame shape and includes strip-shaped partsportions extending in the x direction and strip-shaped partsportions extending in the y direction. The length  $a_{1x}$  of the external side of each strip-shaped partportion extending in the x direction of the frame-shaped electrode 3 is 2.0 mm, the length  $a_{1y}$  of the external side of each strip-shaped partportion extending in the y direction is 2.0 mm, the width  $a_{w_x}$  of the strip-shaped partportion extending in the x direction is 0.18 mm, the width  $a_{w_y}$  of the strip-shaped partportion extending in the y direction is 0.20 mm, and the thickness  $a_{et}$  is 0.01 mm.

[0041] ——Fig. 5(a)A is a plan view of a solder sealing frame 4 used in the electronic component device 20 and Fig. 5(b)B is a cross-sectional view taken along a face including

line C-C in Fig. 5(a)-A. The solder sealing frame 4 has a rectangular frame shape and includes strip-shaped portions extending in the x direction and strip-shaped portions extending in the y direction. The length  $cl_x$  of the external side of each strip-shaped portion extending in the x direction of the solder sealing frame 4 is 2.0 mm, the length  $cl_y$  of the external side of each strip-shaped portion extending in the y direction is 2.0 mm, the width  $cw_x$  of the strip-shaped portion extending in the x direction is 0.18 mm, the width  $cw_y$  of the strip-shaped portion extending in the y direction is 0.20 mm, and the thickness  $ct$  is 0.02 mm. The solder sealing frame 4 is provided on the frame-shaped electrode 3 of the package substrate 1. For example, eutectic solder paste is applied on the frame-shaped electrode 3 of the package substrate 1 by printing and the eutectic solder paste is subjected to reflow soldering. Subsequently, cleaning is performed to remove the flux residue. Thus, the solder sealing frame 4 is formed. In addition to the printing, the solder sealing frame 4 may be formed by precoating such as the SJ process, plating, vacuum deposition, sputtering, or the like. Although eutectic solder is used as the material of the solder sealing frame 4, the material is not limited to eutectic solder as long as the material is a metal that can be melted.

[0042] ——Fig. 4(a)-A is a plan view of the element 10 used in the electronic component device 20 and Fig. 4(b)-B is a cross-sectional view taken along a face including line B-B in Fig. 4(a)-A. The element 10 is a rectangular plate-shaped

surface acoustic wave element. The length  $b_x$  of a side extending in the x direction of the element 10 is 2.0 mm, the length  $b_y$  of a side extending in the y direction is 2.0 mm, the thickness  $b_t$  is 0.35 mm, and the Young's modulus  $E_b$  is 230,000 MPa.

[0043] ——The element 10 includes a piezoelectric substrate 11 composed of quartz crystal,  $\text{LiTaO}_3$ ,  $\text{LiNbO}_3$ , or the like and a functional part provided on the piezoelectric substrate 11. The functional part includes two pairs of IDTs 12 ~~composed~~<sup>made</sup> of Al or the like and four input-output electrodes 13 ~~composed~~<sup>made</sup> of Ti/Ni/Au. The IDTs 12 and the input-output electrodes 13 are connected to each other. The coefficient  $B_x$  of linear expansion of a side extending in the x direction of the element 10 is 16 ppm/ $^{\circ}\text{C}$  and the coefficient  $B_y$  of linear expansion of a side extending in the y direction of the element 10 is 9 ppm/ $^{\circ}\text{C}$ . The coefficient of linear expansion of the side extending in the x direction is different from the coefficient of linear expansion of the side extending in the y direction.

[0044] ——A frame-shaped electrode 14 serving as a first frame-shaped electrode is provided on the surface of the element 10 so as to surround the IDTs 12 and the input-output electrodes 13. The frame-shaped electrode 14 has a rectangular frame shape and includes strip-shaped ~~parts~~<sup>portions</sup> extending in the x direction and strip-shaped ~~parts~~<sup>portions</sup> extending in the y direction. The length  $b_{lx}$  of the external side of each strip-shaped ~~part~~<sup>portion</sup> extending in the x direction of the frame-shaped electrode 14 is 2.0 mm,

the length  $b_{1y}$  of the external side of each strip-shaped partportion extending in the y direction is 2.0 mm, the width  $bw_x$  of the strip-shaped partportion extending in the x direction is 0.18 mm, the width  $bw_y$  of the strip-shaped partportion extending in the y direction is 0.20 mm, and the thickness bet is 0.001 mm.

[0045] ——As shown in Fig. 2(a)A, bumps 15 are fixed on the input-output electrodes 13. The bumps 15, which are Au bumps, are formed by a wire bonding process. In place of the Au bumps, metal bumps mainly ~~composed~~made of Ag, Pd, and Cu-solder bumps, or the like may also be used. In place of the wire bonding process, the bumps 15 may be formed by plating, a process of setting solder balls, printing, or the like. The height of the bumps 15 is preferably higher than the height of the solder sealing frame 4 formed on the package substrate 1 and is preferably about 40  $\mu\text{m}$  to about 50  $\mu\text{m}$ .

[0046] ——In the package substrate 1 and the element 10, the length of the sides extending in the x direction and the length of the sides extending in the y direction are substantially the same. Each of the bonding electrodes 2 of the package substrate 1 and each of the input-output electrodes 13 of the element 10 are disposed at corresponding positions. The frame-shaped electrode 3 of the package substrate 1 and the frame-shaped electrode 14 of the element 10 are also disposed at corresponding positions.

[0047] ——The frame-shaped electrodes 3 and 14 are ~~composed~~made of Ni/Au. Nickel is used in order to prevent solder corrosion. A metal other than Ni may be used as long

as the metal can prevent solder corrosion. In addition to Ni, examples of such a metal include Pt and Pd. Gold is used in order to ensure solderability. A metal other than Au may be used as long as the metal can ensure solderability. In addition to Au, examples of such a metal include Ag, Sn, Pt, and Cu.

[0048] ——A method for bonding the package substrate 1 and the element 10 will now be described.

[0049] ——As shown in Fig. 2(a)A, an element 10 including IDTs 12, input-output electrodes 13, a frame-shaped electrode 14, and bumps 15 and, as shown in Fig. 2(b)B, a package substrate 1 including bonding electrodes 2, a frame-shaped electrode 3, and a solder sealing frame 4 are prepared.

[0050] ——The package substrate 1 is placed on a support such that the solder sealing frame 4 is disposed on the upper side, and the position of the package substrate 1 is fixed. Subsequently, the reverse face of the element 10 is sucked applied with a vacuum with a bonding tool. The element 10 is positioned such that the frame-shaped electrode 3 of the package substrate 1 and the frame-shaped electrode 14 of the element 10 correspond below and above. Subsequently, a pressure is applied with ultrasonic waves using the bonding tool to bond the bumps 15 with the bonding electrodes 2 of the package substrate 1. Thereby, the bumps 15 and the bonding electrodes 2 of the package substrate 1 undergo diffusion bonding. At the same time, the melted solder sealing frame 4 is spread on the frame-shaped electrode 14 of the element 10 with wettability to hermetically seal the space between the

package substrate 1 and the element 10.

[0051] — Finally, the resulting package substrate 1 and the element 10 are cooled to complete the bonding and sealing. Thus, a hermetically sealed electronic component device 20 can be produced.

[0052] — With respect to the electronic component device 20, the differences  $Q_x$  and  $Q_y$  in expansion generated between the package substrate 1 and the element 10 will be calculated.

[0053] — The differences  $Q_x$  and  $Q_y$  in expansion in the electronic component device 20 are calculated as follows: The difference  $Q_x$  in expansion is  $|7 \text{ ppm}/\text{°C} - 916 \text{ ppm}/\text{°C}| \times 2.0 \text{ mm} = 4.01.8 \times 10^{-76} \text{ mm}/\text{°C}$ , and the difference  $Q_y$  in expansion is  $|7 \text{ ppm}/\text{°C} - 169 \text{ ppm}/\text{°C}| \times 2.0 \text{ mm} = 1.84.0 \times 10^{-67} \text{ mm}/\text{°C}$ . Thus, the difference  $Q_y Q_x$  in expansion is larger than the difference  $Q_x Q_y$  in expansion.

[0054] — In the electronic component device 20, the width  $cw_x$  of the strip-shaped partportion extending in the x direction of the solder sealing frame 4 and widths  $aw_x$  and  $bw_x$  of the strip-shaped partsportions extending in the x direction of the frame-shaped electrodes 3 and 14, respectively, are 0.2018 mm. On the other hand, the width  $cw_y$  of the strip-shaped partportion extending in the y direction of the solder sealing frame 4 and widths  $aw_y$  and  $bw_y$  of the strip-shaped partsportions extending in the y direction of the frame-shaped electrodes 3 and 14, respectively, are 0.1820 mm. In the electronic component device 20, the difference  $Q_y Q_x$  in expansion is larger than the difference  $Q_x Q_y$  in expansion. That is, the widths  $aw_y$ ,  $bw_y$ ,  $aw_x$ ,  $bw_x$ , and  $cw_y$ ,  $cw_x$  of the strip-

shaped partsportions extending in the  $\mathbf{yx}$  direction of the frame-shaped electrodes 3 and 14 and the solder sealing frame 4 are smaller than the widths  $aw_x$ ,  $bw_x$ ,  $aw_y$ ,  $bw_y$ , and  $ew_x$ ,  $cw_y$  of the strip-shaped partsportions extending in the  $\mathbf{xy}$  direction.

[0055] ——When the width of the strip-shaped partportion extending in the direction in which the larger difference in expansion is generated between the differences  $Q_x$  and  $Q_y$  in expansion is smaller than the width of the strip-shaped partportion extending in the direction in which the smaller difference in expansion is generated between the differences  $Q_x$  and  $Q_y$  in expansion, the electronic component device 20 can be miniaturized. On the other hand, in the solder sealing frame 4 and the frame-shaped electrodes 3 and 14, the maximum equivalent strains generated in the sides extending in the direction in which the larger difference in expansion is generated are barely changed. Accordingly, the electronic component device 20 can satisfy the lifetime for thermal shock resistance required for general electronic component devices.

[0056] ——Furthermore, in the electronic component device 20, the thickness  $ct$  of the solder sealing frame 4 is 0.02 mm (20  $\mu\text{m}$ ). By increasing the thickness of the solder sealing frame 4 to about 18  $\mu\text{m}$  or more, when a thermal shock is applied during a reliability test or during use, a strain generated at the sealed portion between the package substrate 1 and the element 10 can be absorbed by the solder sealing frame 4. Accordingly, in the electronic component device 20, the maximum amplitude of equivalent strain generated in the solder sealing frame 4 can be reduced to about 2.2% or less.

[0057] ——In the electronic component device 20, the difference  $Q_y - Q_x$  in expansion is larger than the difference  $Q_x - Q_y$  in expansion. Accordingly, when the difference  $Q_y - Q_x$  in expansion is about  $2.2 \times 10^{-5}$  mm/ $^{\circ}$ C or less, the maximum amplitude of equivalent strain generated in the solder sealing frame 4 can be reduced to about 2.2% or less. Since the difference  $Q_y - Q_x$  in expansion is about  $1.8 \times 10^{-6}$  mm/ $^{\circ}$ C, which satisfies the condition of about  $2.2 \times 10^{-5}$  mm/ $^{\circ}$ C or less, in the electronic component device 20, the maximum amplitude of equivalent strain generated in the solder sealing frame 4 can be reduced to about 2.2% or less.

[0058] ——With respect to the electronic component device 20, the ratios  $R_x$  and  $R_y$  of flexural rigidity in the package substrate 1 and the element 10 will be calculated.

[0059] ——The ratios  $R_x$  and  $R_y$  of flexural rigidity in the electronic component device 20 are calculated as follows: The ratio  $R_x$  of flexural rigidity is  $(0.25^3 \text{ mm} \times 2.0 \text{ mm} \times 340,000 \text{ MPa}) / (0.35^3 \text{ mm} \times 2.0 \text{ mm} \times 230,000 \text{ MPa})$  and the ratio  $R_y$  of flexural rigidity is  $(0.25^3 \text{ mm} \times 2.0 \text{ mm} \times 340,000 \text{ MPa}) / (0.35^3 \text{ mm} \times 2.0 \text{ mm} \times 230,000 \text{ MPa})$ . The ratio  $R_x$  of flexural rigidity and the ratio  $R_y$  of flexural rigidity are the same value of about 0.54.

[0060] ——The ratios  $R_x$  and  $R_y$  of flexural rigidity in the electronic component device 20 are about 0.54, which satisfies the condition of about 1.2 or less. Therefore, in the electronic component device 20, the maximum amplitude of equivalent strain generated in the solder sealing frame 4 can be reduced to about 2.2% or less.

[0061] ——As described above, the maximum amplitude of equivalent strain generated in the solder sealing frame 4 can be reduced to about 2.2% or less in the electronic component device 20. Consequently, even when a thermal shock is applied during a reliability test or during use, a strain or a fatigue breaking that is generated in the solder sealing frame 4 can be suppressed and thus sealing failure due to breaking of the sealed portion does not occur.

[0062] ——Consequently, the electronic component device 20 has further improved lifetime for thermal shock resistance and excellent reliability.

[0063] ——In the above preferred embodiment, the solder sealing frame 4 is provided on the package substrate 1. Alternatively, the solder sealing frame 4 may be provided on the element 10 or may be provided on each of the package substrate 1 and the element 10. When the solder sealing frames 4 are provided on both the package substrate 1 and the element 10, the solder sealing frames are bonded with each other to perform sealing.

[0064] ——With respect to the solder sealing frame 4, the solder sealing frame 4 need not be entirely composedmade of a base metal. It is sufficient that at least the surface thereof is composedmade of a base metal.

[0065] ——In place of metal bumps or solder bumps, base metal bumps such as Al bumps may be used as the bumps 15.

[0066] ——A surface acoustic wave element is used as the element 10 in the above preferred embodiment. Alternatively, another element such as a high-frequency element may also be

used as long as the coefficient of linear expansion in the x direction is different from the coefficient of linear expansion in the y direction.

[0067] —A glass epoxy resin is used for the package substrate 1 in the above preferred embodiment. Alternatively, another airtight substrate ~~having airtightness~~, for example, a glass substrate, a ceramic substrate ~~composed~~made of alumina or the like, or a crystalline substrate may also be used.

[0068] —The solder sealing frame 4 may be connected to an earth-side circuit pattern (not shown in the figure) provided on the package substrate 1.

[0069] —While the present invention has been described with respect to preferred embodiments thereof, it will be apparent to those skilled in the art that the disclosed invention may be modified in numerous ways and may assume many preferred embodiments other those specifically set out and described above. Accordingly, it is intended by the appended claims to cover all modifications of the present invention which fall within the true spirit and scope of the invention.